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MUNICIPAL WASTE WATER TREATMENT WITH SPECIAL REFERENCE TO THE CENTRAL WASTE WATER TREATMENT PLANT IN POZNAN, POLAND

Bachelor's Thesis

CENTRAL OSTROBOTHNIA UNIVERSITY OF APPLIED SCIENCES

Degree programme in Chemistry and technology

April 2010

CENTRAL OSTROBOTHNIA UNIVERSITY OF APPLIED SCIENCES	**THESIS ABSTRACT**
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Degree programme in Chemistry and Technology	
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Topic Municipal wastewater treatment with special reference to the central wastewater treatment plant in Poznan, Poland.	
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Date: 16^{th} April, 2010	**Pages: 41**

Wastewater treatment is becoming a more critical topic due to diminishing water resources, increasing cost of disposing wastewater and also stricter measures and legislations set by environmental protection agencies regarding the permissible contaminant levels of effluent disposal into water bodies.

Wastewater from municipalities is significant as it comes in large volumes due to the level of usage by residential areas and industries. This thesis gives an insight into the various stages, methods and technologies used in treatment of wastewater.

The thesis also discusses the management of treated effluent which includes approaches about their reuse and disposal possibilities.

As regards the Poznan, Poland angle, the thesis contains a description of the treatment methods for the city of Poznan's wastewater accumulation and some experimental results and procedures carried out at the treatment facility where I was attached during my training.

Keywords: Biological oxygen demand (BOD), Influent, Effluent, Sludge, micro-organisms, treatment facility, biogas.

FOREWARD

This bachelor's thesis has been made as part of my studies in the Chemistry and Technology engineering degree programme with specialisation in Environmental Technology.

First of all I want to thank the almighty God for his mercies and irreplaceable support all through my studies in Kokkola and for the wisdom and vision granted to complete this thesis.

I also want to use this medium to acknowledge the invaluable roles of all persons who contributed in one way or the other to make this thesis a success. Special cognisance goes to my parents Mr and Mrs Orukpe T.U who were always there for me when it mattered most. I would also like to thank my brothers and sisters ranging from Ebehita, Irenonse, Omonze, Oseribho and Samson for their relentless support all through my study time. I also want to specially thank my loving wife Hanna and daughter Onokahinvie Silvia Leonora who gave me all the support and inspiration I needed at trying times. I won't fail to mention my profound gratitude to my friend Ola for his role in everything. My regards also to the Cwiertnia crew for their relentless support during my research and training with their company which aided the compilation of this thesis.

I won't forget to mention my undiluted gratitude to the entire Central Ostrobothnia University of Applied Sciences staff and students for their support one way or the other. My special thanks go to my thesis supervisor, Kaj Jansson, Esko Johnson and all other lecturers in my department for their reliability and invaluable support. I also want to state that the list is endless so to everyone who contributed one way or the other, I say thank you.

Kokkola, April 2010

Orukpe Otaigbe Stephen

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1 INTRODUCTION

With the ever growing need for a healthy and conducive environment for humanity, there is growing need to confront the threat posed by water whose quality has been negatively impacted upon due to numerous human and natural activities.

Municipal waste water is the combination of liquid or water-transported waste which has originated from residential dwellings, commercial, or industrial facilities and institutions. It also comprises of ground water, surface water, and rain or storm water that may be present at the time. Raw waste water usually comprises of high level concentration of organic materials, numerous pathogenic micro organisms, and also numerous nutrients and toxic components.

The primary reason for waste water treatment and management is protection and management of the environment in such a way that the environment is viable and good enough for habitation and also to make sure that the health of the public is not jeopardised by the threat posed by waste water. Treatment ensures that the resultant effluent after treatment is disposable to water bodies without causing pollution, harm to the aquatic life and the environment at large. The function of the treatment plant is to speed up the natural process by which water purifies itself. The most common forms of water pollution control are the use of a system of sewers and water treatment facilities. Sewers collect municipal waste water from residential areas, industries and business establishments and transfer the water deposits to a treatment facility which comprises of sophisticated machines which carefully treat the waste water stage by stage depending on the composition.

This aim of this thesis and research is to analyse the concept of wastewater treatment and also to narrow it down to the way and manner it is being carried out at the treatment facility in the city of Poznan in western Poland. The thesis gives an overview of the treatment techniques and important contaminant removal methods. It contains also experimental data and information which goes to show the efficiency of the entire treatment process with respect to the treatment facility in Poznan, Poland.

Several environmental protection agencies set maximum contaminants and treatment efficiency levels for effluents. They also dictate effluent discharge parameters so as to promote a healthy and less harmful aquatic and natural environment for plants and animals alike. Also there is the topic about the reuse of waste matter such as sludge which is used as a source of methane gas production by the process of anaerobic digestion in a bio-digester.

At every opportunity, nature reminds us by what it does that it is one of those forces humans have little control over so there is no way we can interrupt the rain or commence it, but what is very much possible is becoming much more efficient with the available water. We have to optimise to the highest capacity the available water by imbibing on recycling and reuse policies. As some people say, water is life so every drop counts.

Some research questions which were analysed in this thesis include;

1. What is the reason for treatment?

2. What reuse possibilities are there for treated effluent?

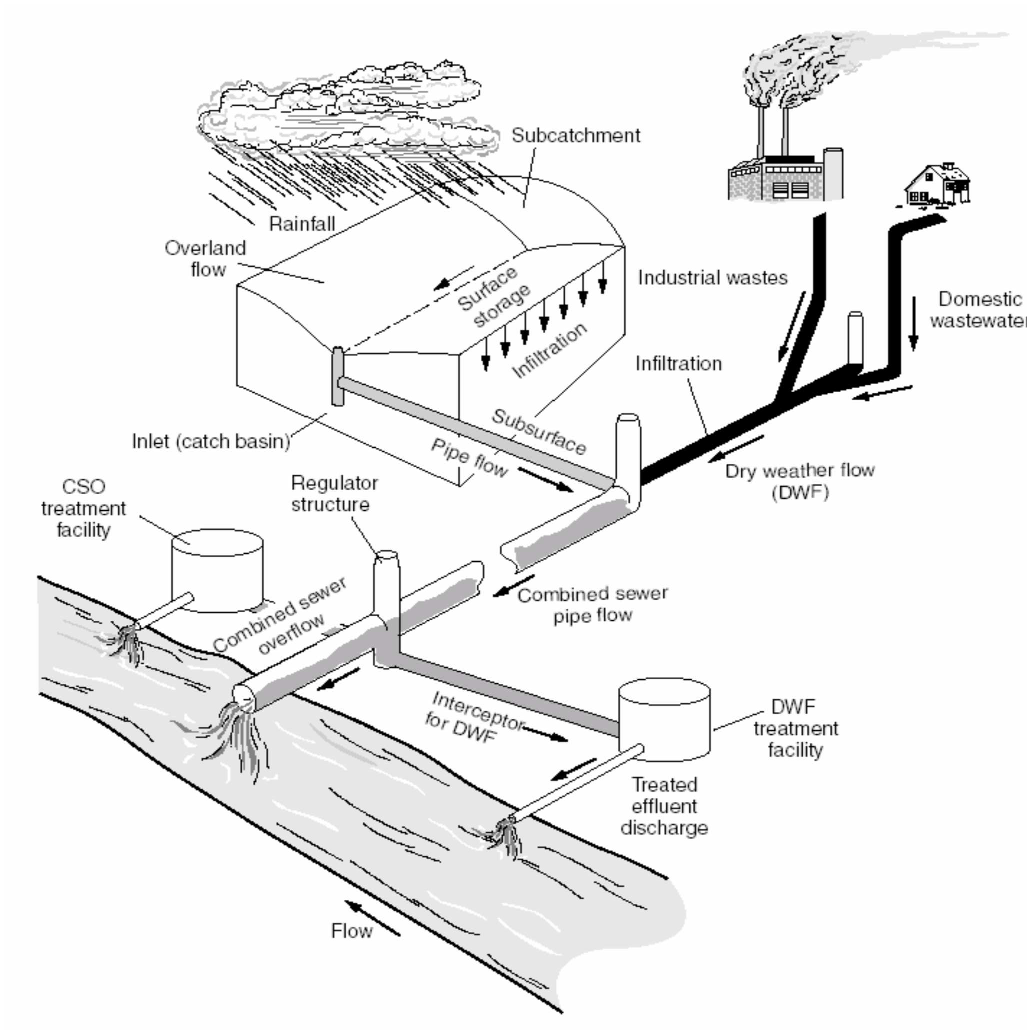
3. What sludge management methods with respect to the plant involved are applied?

4. What is the efficiency of the treatment process with respect to this particular treatment facility?

2 BACKGROUND

2.1 Municipal waste water

Waste water could be defined as potable water which has been contaminated with natural or synthetic microbiological compounds which arise due to human activities, commercial activities, and also industrial activities as the case may be. The characteristics of wastewater discharges would to a great extent vary from location to location depending on the population of the municipality, the amount of industries present, the degree of separation between rain water and sanitary fluids and also the ground water levels. Domestic waste water comprises of wastewater from laundry, bathroom, and kitchen as well as other waste water that people might accidentally or consciously pour down the drain. Sanitary fluids or water comprises of both domestic wastewater as well as those discharged from commercial institutions and similar sources. The photo below shows a diagrammatic representation of wastewater cycle. (Environment Canada 2007; Geostar publishing 2006.)



GRAPH 1. Diagrammatic representation of the wastewater cycle (Tchobanoglous, Burton & Stensel 2003, 2.) Copyright.

Waste water originates predominantly from water usage by residences, commercial and industrial establishments together with ground water, surface water and storm water (see GRAPH 1 above). Wastewater sources could be broadly classified into residential sources and non-residential or industrial sources. For residential sources, most of it originates from our daily activities such as doing laundry, flushing the toilet, dish washing, watering our lawn, and even having a shower. From business sources, we have industrial users, commercial or institutional users, and several other liquid waste services. Waste water from industrial, commercial and institutions creates a very unique demand for the treatment facilities because they contain very complex contaminants as compared to residential wastewater sources therefore treatment costs are generally higher. Most recent sewage systems are independent in nature i.e. they collect sanitary and storm water as compared to older ones which collect sanitary and storm water in a combined system. (Geostar publishing 2006; Environment Canada 2007.)

The physical appearance of most wastewater is greyish in colour usually accompanied with musty and offensive odour. It is usually composed of a solid content of about 0.1% and water content of about 99.9%. The solid content could appear as suspensions or be totally dissolved into the water. These suspensions could lead to the production of sludge deposits and anaerobic conditions when deposited into the surroundings. Dissolved solids could be precipitated by chemical and biological procedures. (Environment Canada 2007.)

The toxic nature of municipal effluents depends hugely on a variety of parameters which include the size and nature of the sewer-shed, the type and efficiency of treatment and disinfection, the physical, and the chemical and biological features of the receiving water bodies. In most cases, the relative toxic level of municipal waste water is due to unionised ammonia. In the case chlorinated waste water, it is due to the amount of chlorine residue present to make water toxic. Other possible causes of waste water contamination include cyanide, Phenol, sulphides, surfactants, heavy metals such as copper, chromium, lead and zinc. Several factors which include the hardness, PH value, the amount of dissolved organic carbon can affect the toxic level of the water treatment plant effluent or the receiving environment. Many chemical substances detected in municipal waste water are hydrophobic in nature and tend to be absorbed into the particles present in the effluent or sediments in the receiving environment rather than remain in the water phase. Therefore the distribution rate of these chemicals would differ from more soluble constituents which would tend to move in the effluent plume. (Geostar Publishing 2006.)

2.2 Why treat wastewater?

The basic reason for treating waste water is simply to transform it into a more useful form and also to make sure that water to be disposed off to water bodies if not potable is at least not harmful to aquatic and human life. This is achieved when the effluent recovered after treatment is relatively harmless and contains little or no amount of contaminants and is disposed appropriately into water bodies such as rivers and lakes or reused as the case may be.

The world's supply of fresh and healthy public water is fast depreciating. Most of the diseases plaguing the world today are water borne. This is a big source of concern given that fact that man cannot live or exist without water. Statistically, about 40% of the world's population is already plagued with the problem of scarcity.

According to the United Nations (UN), water crisis is amongst one of the most serious crisis affecting the world today so there is need for this topic to be given the attention that it deserves. Many people however are not really concerned about waste water treatment until they are directly affected by contaminated water. Clean water is important to aquatic animals, organisms and plants. It is important to the fishing industry, sport fishing enthusiasts and future generations that water bodies are kept in a reasonably clean level. (Geostar Publishing 2006.)

2.3 Important parameters used to define the strength of wastewater

Generally, the analysis methods for the organic matter content of wastewater could be divided into those applied for measurement of macro concentrations i.e. 1mg/l and above and the measurement of micro or trace concentrations i.e. $10^{-12} \rightarrow$ 1mg/l.

For macro concentrations of organic matter, the main parameters employed include; biochemical oxygen demand, chemical oxygen demand and total organic carbon.

2.2.1 Biochemical oxygen demand (BOD)

The most widely used parameter for organic pollutants in wastewater and surface water analysis is the 5-day biochemical oxygen demand (BOD_5). The widest application of BOD is in measuring wastewater supplies to treatment plants and in evaluation of the efficiency of the treatment process and system. In addition, the BOD is used to determine oxygen requirements to treated effluent and polluted waters. The BOD test procedure is based on the activities of bacteria and other aerobic micro-organisms which feed on organic matter in the presence of oxygen.

By definition, BOD is the amount of dissolved oxygen utilised by a mixed population of micro-organisms in the aerobic oxidation of the organic matter present in a wastewater sample at a temperature of 20^0 C in an air incubator or a water bath. The result of a BOD test indicates the amount of water dissolved oxygen consumed by microbes incubated in darkness for a period of five days. BOD can be used to gauge the effectiveness and efficiency of wastewater treatment plants. It is usually measured in milligrams per litre of water. (Tchobanoglous et al 2003, 81; Hammer 2001, 72.)

2.2.2 Chemical oxygen demand (COD)

Chemical oxygen demand is a term used in wastewater treatment analysis to characterise the organic strength of wastewaters and pollution of natural waters. COD measures the amount of oxygen of the organic matter in a wastewater sample that can be oxidised chemically using a chemical oxidant. Dichromate in an acid solution is usually preferred over the other available methods due to its relatively high oxidising capabilities. The COD test procedure is based on the chemical decomposition of organic and inorganic contaminants either dissolved or suspended in a wastewater sample.

The result of a COD test demonstrates the amount of dissolved oxygen consumed during the chemical decomposition of organic and inorganic matter in a specified period of time for example two hours. The higher the chemical oxygen demand, the higher the amount of contaminants or pollutants in the sample. So we can say the COD is directly proportional to the impurity level of the water sample. COD is usually measured in milligrams per litre of water. (Tchobanoglous et al 2003, 94; Hammer 2001, 41.)

2.2.3 Total organic carbon (TOC)

The total organic carbon is a parameter used in analysing the purity of wastewater samples. It determines the total organic carbon present in an aqueous sample. The test methods for TOC makes use of heat and oxygen, chemical oxidants, ultraviolet radiation or a combination of any of these to transform organic carbon to carbon dioxide which is measured with the aid of an infrared analyser or by other means. The TOC test is in some cases related to BOD and COD tests and it is used for process control. More recently, a continuous online TOC test analyzer has been invented and could be used to determine

TOC concentrations in part per billion ranges. Such facilities are already being used to monitor concentrations of treated effluents.

The TOC analyzer works in such a way that acid is added to the wastewater sample so as to eliminate the inorganic carbon and give off carbon dioxide gas which is then stripped out of the liquid. The remaining inorganic carbon-free sample is then oxidised and the carbon dioxide generated from the oxidation process is directly proportional to the TOC in the sample. (Tchobanoglous et al 2003, 95; Hammer 2001, 42.)

3 COMPONENTS OF MUNICIPAL WASTEWATER

Waste water quality could be defined by its physical, chemical or biological characteristics. Physical parameters include colour, odour, temperature and turbidity. Insoluble contents such as oil, grease, solids also fall under this criterion. Solids may further be classified into suspended and dissolved solids as well as organic (volatile) or inorganic (fixed) fractions. Chemical parameters associated with the organic composition of waste water include biochemical oxygen demand (BOD), Chemical oxygen demand (COD), total organic carbon (TOC), and the total oxygen demand (TOD). Inorganic chemical parameters are hardness, PH, acidity, and alkalinity as well as compounds of sulphides, nitrates and phosphates. Bacteriological acronyms include coliforms, specific pathogens, viruses, and faecal coliforms. Generally waste water is classified as either; weak, medium or strong.

Table 2. The typical composition of raw or untreated domestic wastewater (Tchobanoglous et al 2003, 186.)

Contaminants	Unit	Concentrations		
		Weak	Medium	Strong
Total Solids (TS)	Mg/l	390	720	1230
Total Dissolved Solids	Mg/l	270	500	860
Fixed	Mg/l	160	300	520
Volatile	Mg/l	110	200	340
Suspended Solids	Mg/l	120	210	400
Fixed	Mg/l	25	50	85
Volatile	Mg/l	95	160	315
Settleable Solids	Mg/l	5	10	20
BOD_5, 20^oC	Mg/l	110	190	350
TOC	Mg/l	80	140	260
COD	Mg/l	250	430	800
Nitrogen(total as N)	Mg/l	20	40	70
Organic	Mg/l	8	15	25
Free Ammonia	Mg/l	12	25	45
Nitrites	Mg/l	0	0	0
Nitrates	Mg/l	0	0	0
Phosphorus(total as P)	Mg/l	4	7	12
Organic	Mg/l	1	2	4
Inorganic	Mg/l	3	5	10
Chlorides	Mg/l	30	50	90
Sulphate	Mg/l	20	30	50
Oil and Grease	Mg/l	50	90	100
Total coliform	No/100ml	$10^6 – 10^8$	$10^7 – 10^9$	$10^7 – 10^{10}$
Fecal coliform	No/100ml	$10^3 – 10^5$	$10^4 – 10^6$	$10^5 – 10^8$
Volatile Organic compounds	mg/l	<100	100 - 400	>400

3.1 Important contaminants in wastewater

The effects of the spreading of wastewater into the neighbouring surroundings and environment are a function of the nature and concentration of the contaminated pollutant. The most important contaminants with respect to their potential effect on receiving water bodies and treatment concerns are analysed in the table 3 below.

TABLE 3. Important contaminants in wastewater (Tchobanoglous et al 2003, 32.)

Contaminants and their reason for importance
Suspended solids (SS) can give rise to development of anaerobic conditions and sludge deposits when raw wastewater is given off to the aquatic environment. **Biodegradable Organics** basically are made up of proteins, carbohydrates and fats. They are commonly measured in terms of COD and BOD. If given off to the inland rivers, lakes and other water bodies, their biological stability could deplete natural oxygen resources and give rise to septic conditions that are detrimental to aquatic life. **Refractory organics:** These tend to oppose conventional wastewater treatment and typical examples of such include agricultural pesticides, surfactants and phenol. **Priority pollutants**: These are organic and inorganic compounds which may be highly mutagenic, carcinogenic, teratogenic and toxic as the case may be. Many of such compounds are present in raw wastewater samples. **Pathogenic organisms:** These are found in wastewater and could give rise to infectious diseases which would be detrimental to human health. **Heavy metals:** These are usually supplied to the wastewater by industrial and commercial activities must be evacuated so as to make reuse of wastewater possible. **Dissolved organics:** These are added to wastewater through the everyday use of water and they have to be eliminated in order for treated effluent to be able to be reused. They include elements such as calcium, sulphates, and sodium. **Nutrients:** Elements such as phosphorus and nitrogen are important for growth. When they are discharged alongside treated effluent into water bodies, there is growth of undesirable aquatic life. Also when they are discharged excessively on land, they go into the groundwater and pollute it.

4 WATSEWATER TREATMENT LEVELS AND PROCESSES

4.1 Wastewater treatment levels

Wastewater treatment levels could be generally divided or categorised into three criterions based on the activity that is undertaken in each of the stages. These criterions include preliminary, primary, secondary, and tertiary or advanced treatment.

4.1.1 Preliminary treatment

As wastewater flows into a treatment facility, it undergoes a first stage operation called preliminary treatment. The aim of this stage of treatment is to eliminate debris that are untreatable and could be taken off by physical means. This first stage makes use of screens to remove the larger inorganic materials such as paper, plastic materials, rags, cans bottles, wood, clogs and other physical debris that may be present at the time. This operation is necessary because the influent wastewater has to be prepared for further treatment in the plant by reducing or completely eliminating unfavourable influent characteristics that might obstruct operation process or excessively increase operation and process costs. The screens are usually made up of parallel steel and metal bars with openings. Preliminary treatment comprises of physical unit operations. Other preliminary treatment operations include flow equalization and odour control. The eliminated debris is then collected and deposited in landfills. Following screening, mechanically mixed basins are used to remove and grit and sand-like material that might be present before the effluent is transferred to the primary treatment section. (SA Water 2010; Clean water services 2010.)

4.1.2 Primary treatment

As the name suggests, primary treatment is the process which involves the partial elimination of suspended solids and organic materials from wastewater with the aid of physical operations such as screening and sedimentation. This primary treatment occurs in the primary sedimentation tanks or primary clarifiers as the case may be. Inside the clarifier is a mechanically operated large rotating arm or blade which simultaneously remove the settled solids from the bottom of the clarifier and the grease, oil, and other floatables are separated from the top of the clarifier. This primary sedimentation tanks or clarifiers are covered and always kept in vacuum and also an odour reduction and controlling facility helps to manage odour which is mostly hydrogen sulphide gas which emanates from the wastewater. Pre-aeration or mechanical flocculation with the aid of some special chemicals can be used to facilitate primary treatment.

Primary treatment acts as a prerequisite for secondary treatment. Its goal is to produce or bring about the production of a liquid effluent which would be suitable for the downstream biological treatment and also separating out solid waste materials as sludge which can then be easily treated before the final disposal. The effluent which is produced after primary treatment still contains a good amount of organic materials i.e. about 30% of the original suspended solids that were in the plants influent stream and it is characterised also by a high biological oxygen demand (BOD) i.e. about 70% of the original BOD level but it is remarkably cleaner than the original influent that first came into the plant at the beginning. (Sydney water 2010; City of Lewisville 2010; Clean water services 2010.)

GRAPH 2. Primary clarifiers or sedimentation tanks being covered and kept in vacuum so as to control the odour which emanates from the raw waste water influent.

4.1.3 Secondary treatment

The main purpose of secondary treatment is to break down dissolved and suspended organic solids materials in the influent wastewater which could not be eroded during the primary treatment through bacterial decomposition. This is achieved by the use of naturally occurring micro-organisms in biological processes which includes; activated sludge process, fixed-film reactors, or lagoon systems or sedimentation.

Basically, the effluent from the primary treatment flows into secondary sedimentation tanks where the bacteria grows and naturally treats the waste water. In the end after the bacterial activity, the effluent is sent to secondary clarifiers. Just as in the primary clarifiers, the effluent is then separated with the aid of mechanical rakes and gravity. In this case, the micro organisms bind together as floc and then more sediments and particles settle at the base of the bioreactor for collection. Most of the floc is channelled back into the bioreactors while a small portion is evacuated and broken down as sludge along with the rest of the solid waste matter. (City of Lewisville 2010; EPCOR Utilities Inc 2010.)

4.1.4 Tertiary treatment

Tertiary treatment as the name suggests further eliminates inorganic components such as plant nutrients nitrogen and phosphorus. The level of treatment required before discharge of the effluent to water bodies depends on the water quality of the receiving water body and also the nature of the reuse designated for the treated effluent. Usually there are standards and guidelines provided by the various environmental monitoring agencies in different locations as regards the quality of treated of effluent wastewater to be discharged to water bodies or to be reused for other purposes.

Tertiary treatment goes beyond conventional secondary treatment to eliminate significant amount of nitrogenous compounds, phosphorus, heavy metals, bacteria, viruses, and other biodegradable materials present in the effluent. Besides biological nutrient removal procedures, operations usually used in this stage for this purpose include, flocculation, chemical coagulation or thickening, and sedimentation. Also filtration and activated carbon is also applied to the process. Ion exchange and reverse osmosis which are applied for specific ion removal or for reduction of dissolved solids are not so frequently applied at this stage of treatment. (Clean water service 2010.)

After the tertiary treatment process, waste water is commonly disinfected so as to clean any bacteria that may be present after the entire cleansing cycle. A chemical such as sodium hypochlorite is introduced into the effluent at controlled levels. There is a control system which checks and balances the level of chemical to be introduced with respect to the cleansing level to be attained and which makes sure that everything is proportional.

Also disinfection could also be achieved by exposure of the effluent to high intensity ultraviolet light and radiation. These ultraviolet disinfection units are designed to destroy about 99% of all organisms left in the effluent stream after primary, secondary and tertiary treatment. Electromagnetic energy is usually transmitted through the effluent stream and is allowed to penetrate through the exterior membranes of organisms. This process sickens the DNA functionality thereby eliminating all microbiological traces present. Ultraviolet disinfection has several advantages over chlorine disinfection due to the fact that it eliminates the need to transport dangerous chemicals while it de-chlorinates the waste stream and perform complex operations. An ultraviolet facility is usually erected at the plant in such a case. (EPCOR Utilities Inc 2010; Clean water services 2010; IDS Water 2010.)

4.1.5 Nitrogen removal

The presence of nitrogen which brings about the formation of nitrates is an essential plant nutrient therefore high concentration of nitrates in water bodies could bring about excessive growth of plants and algae. This excessiveness may bring about indirect toxic effects on other aquatic animals and organisms. Algal bloom could reduce oxygen concentration in water which thereby puts undue pressure on aquatic animals. Also some breeds of algae could produce some toxins which are harmful to aquatic life and even human life. Excessive levels of nitrate are directly harmful to aquatic animals and could even result in death. When fishes for instance are exposed to nitrates, they would have stunted growth making them smaller than they are supposed to be and even affecting their reproductive health. Bearing these in mind, nitrate concentrations in the effluent has to be eliminated or minimised to the lowest possible level. (Tchobanoglous et al 2003, 60; Environment Canada 2002.)

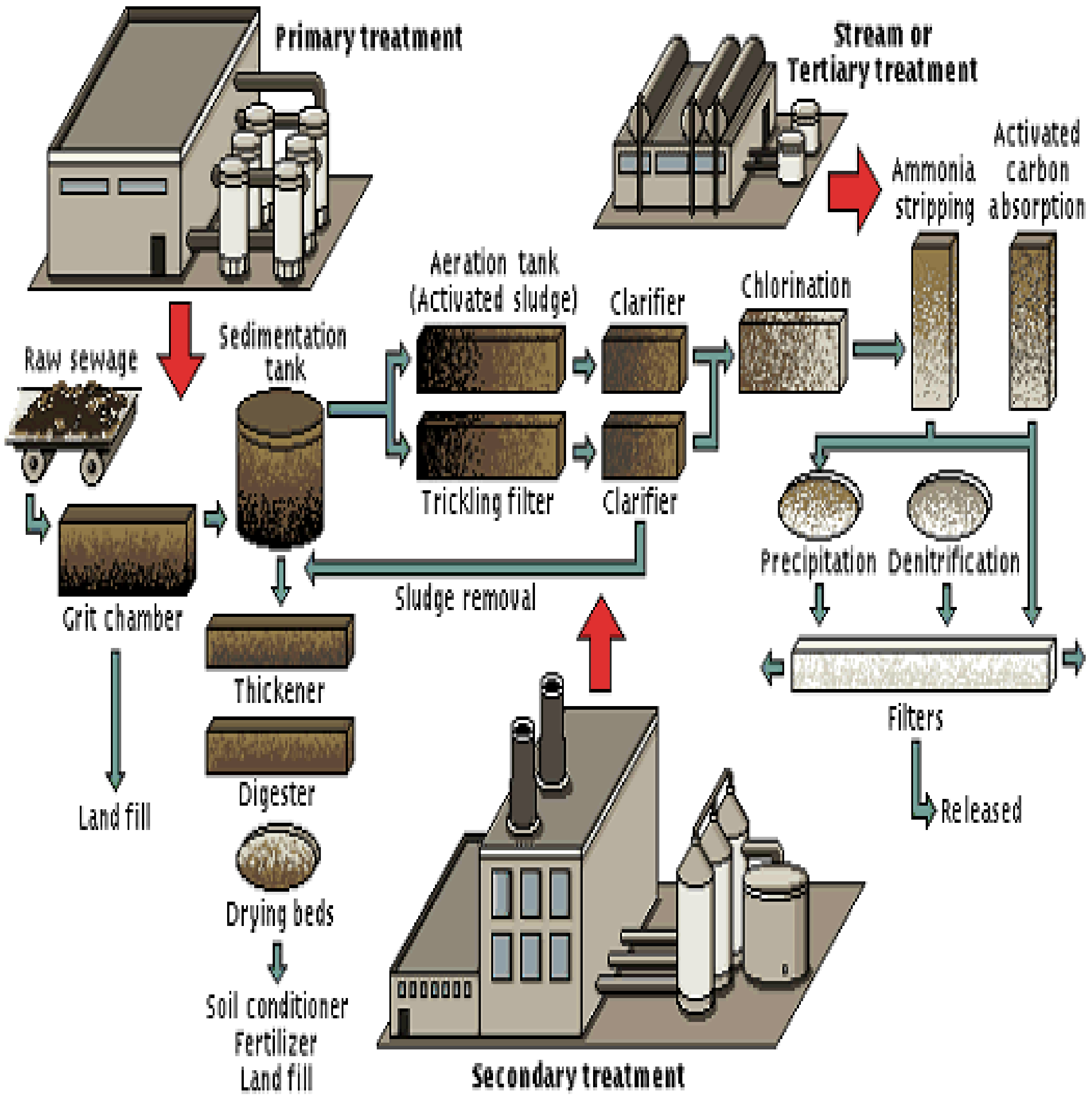
Nitrogen is removed by several methods which come with their advantages and disadvantages. However, the biological removal method is commonly used. In this case, ammonia nitrogen and organic nitrogen are converted into nitrous and nitrate nitrogen in an aerated or aerobic environment and it evolves into the atmosphere as anaerobic nitrogen gas. This conversion is facilitated by the use of a facultative heterotrophic bacterium in the presence of a soluble carbon source. Due to the fact that this process does not create an avenue for secondary pollution, it could be considered as an effective method of de-nitrification of treated effluent. (GEC 2002.)

4.1.6 Phosphorus removal

Phosphorus removal is carried out during effluent purification in the tertiary treatment level. There is need to get rid of phosphorus from effluent so as to prevent eutrophication of surface waters. Eutrophication simply means the increase in the concentration of chemical components in an ecosystem and in this case, water bodies. Phosphorus is one of the main nutrients responsible for the increasing eutrophication of lakes and natural waters.

The process of removing phosphorus from effluent water is currently achieved largely by the use of chemical precipitation. Most commonly coagulant chemicals such as iron sulphate, poly-aluminium chloride and iron chloride are reacted with the effluent. The metal salts react with the phosphates present in the effluent and forms some insoluble precipitate which settles to the bottom of the treatment chamber and are collected as sludge. This process is efficient and eliminates as much as 90% of the phosphorus content and gives an effluent with phosphorus content of less than 1mg/l. This process is expensive and could give rise to a reasonable increase in the amount of sludge formed by the end of the process. An alternative to chemical precipitation is the biological phosphate removal method (BPR).

Normally municipal wastewater contains between 5-20mg/l of phosphorus of which 1-5mg/l is organic while the remaining is inorganic phosphorus. Most legislation require that the phosphorus discharge to surface water and water bodies should be at a maximum of about 2mg/l. Normal secondary treatment can only eliminate about 1-2mg/l from the effluent so the need for tertiary treatment cannot be overemphasised. (Tchobanoglous et al 2003, 63; Lenntech 2009; IDS Water 2010.)



GRAPH 3. Diagrammatic representation of treatment levels and processes (City of Lewisville 2010.) Copyright.

4.2 Typical System components

The biological treatment of wastewater is carried out by micro-organisms which are mainly bacteria and this bacterium degrades the organic matter under either aerobic or anaerobic conditions. The degraded matter is then bound into flock particles and separated as sludge.

Under anaerobic conditions, biological degradation is carried out in the absence of oxygen, so the microorganisms make use of nitrate as the oxidizing agent. The organic substances are oxidized into carbon dioxide and water, while some part of the matter is degraded into methane gas

Under aerobic condition which is the more commonly used approach for wastewater treatment, oxygen must be supplied to support the biological processes. Here again, the organic material is oxidized into mainly carbon dioxide and water, and some part of the organic material is used to support bacterial growth. Aerobic biological treatment is usually performed using either a fixed-film process or activated sludge process.

4.2.1 Fixed film biological treatment process

These systems let the wastewater pass through a substrate while the entire treatment stream is oxygenated. The culture of micro-organisms that grows on the substrate consumes the organic matter in the wastewater. As the layer of micro-organisms grows thicker, it periodically sloughs off and ends up in the wastewater effluent stream. The micro-organisms are separated as sludge in an adjacent settling basin. (Ataei A. 2010, 34.)

4.2.2 Activated sludge treatment process

By comparison, biological treatment systems that make use of the activated-sludge process keeps the sludge which contains the micro-organisms suspended in the basin thereby relying on some type of aeration device to deliver air or oxygen to the wastewater in order to support the metabolic processes of the aerobic micro-organisms. To achieve an adequate rate of organic degradation, a portion of the sludge in continuously recycled and a small amount of sludge is periodically removed and sent for digestion in a bio-digestion tank or facility. (Aatei A. 2010, 34.)

4.2.3 Aeration process

During fixed film and activated-sludge processes, the micro-organisms feed on organic substances, reducing the amount of organics in the wastewater. Additionally, bacteria transform ammonium which originates from urine, into nitrate. This makes de-nitrification a vital part of ongoing purification process.

Air is later supplied using individually controllable, high-capacity compressors, which produces an airflow that corresponds to the amount of biological oxygen demand (BOD) in the inlet stream. Aeration systems also provide mixing, which helps to keep solids suspended. (Ataei, A. 2010, 34.)

5 TREATED EFFLUENT MANAGEMENT

When treatment is complete, the effluent stream is either discharged to water bodies or reused for several purposes. Quality effluent could be utilised in processes such as agricultural irrigation, industrial recycling, groundwater recharge, non-potable urban reuse and in some cases, potable urban reuse. If treated effluent is not reused, it is therefore diluted and usually discharged in to the water bodies and aquatic life. Environmental agencies such as the environmental protection agency (EPA) in the United States of America for example create and regulate effluent disposal guidelines and policies so as to ensure tolerable effluent disposal levels. (Hammer 2001, 511; Ataei, A 2010, 34.)

5.1 Effluent reclamation and reuse

Recently there has been a renewed sense of interest in effluent reclamation and reuse policies which is hugely due to the high consumption and demand for consumable and utilisable water supply. When water is to be used for its numerous purposes, there is always a question about its purity. This question gives rise to concerns about wastewater treatment procedures and processes. This section of my thesis would try to elaborate and highlight the reusable nature of effluent (treated wastewater) with reference to effluent quality issues.

5.1.1 Industrial uses

Industries which need water which doesn’t have to be of potable quality make use of high supplies or treated effluent. This therefore makes this kind of water very ideal for many industrial processes. Industrial uses of treated effluent include; boiler feed water, process water, evaporative cooling water, irrigation and maintenance of the ground and landscape around the industry or plant as the case may be.

Even as effluent supplies remains very useful in industrial scale, it poses its own problems depending on the nature of its reuse. For instance the use of effluent water in cooling towers could result in some problems such as scaling, biological growth, corrosion, fouling, and also foaming. Inasmuch as these problems are encountered even when fresh water is used, it is less frequent and if at all, it is usually in a much lighter scale. If effluent water is to be utilised as boiler feed water, it should be softened and demineralised just as process water quality depends largely on the nature of the industrial process to be undertaken. (Hammer 2001, 514; Tchobanoglous et al 2003, 1412.)

5.1.2 Irrigational uses

Treated wastewater could be utilised for agricultural irrigation purposes. The major concern in this case is the quality of the effluent and its suitability and side effects on plant growth. Those parameters which are always considered important when effluent is to be used for irrigation include presence of toxic chemicals, residual chlorine, dissolved solids and other nutrients. Also the health of the general public is taken into consideration with reference to the presence of harmful components such as intestinal parasites, protozoa, bacterial pathogens and viruses. There are a few constraints about the use of effluent water for irrigation purposes. These concerns range from the acceptability and marketability of crops, groundwater and surface water pollution if there is inadequate management, cost of pumping the effluent to the irrigation location, and also high user costs. (Hammer 2001, 512; Tchobanoglous et al 2003, 1401.)

5.1.3 Potable reuse

This is a topic that is being debated on a regular basis. Due to the sensitive nature of the human body, there is extensive caution as to the use of effluent as potable water. This is because of health concerns, public pessimism about the suitability of effluent for drinking, and aesthetic concerns i.e. appearance and taste. There is numerous research works on the subject matter but constraints remain unresolved as regards the quality criteria of such water. As things are at present, potable reuse of effluent is often limited to extreme cases and conditions where fresh water availability is virtually impossible. (Tchobanoglous et al 2003, 1429.)

5.1.4 Groundwater recharge

When applying the groundwater recharge method of positively utilising effluent, it goes a long way to enhance water table levels, protect groundwater in coastal aquifers against salt-water intrusion, and store effluent water for future uses. Groundwater recharge methods range from surface spreading in basins to direct injection into aquifers. Surface spreading makes use of flooding, ridge and furrow, constructed wetlands, and infiltration basins

This method of application improves the quality of the effluent water to a great extent as it percolates successively through layers of soil, unsaturated zone and aquifer. Direct injection involves the pumping of the effluent water directly into an aquifer. The constraints of this method include high effluent treatment costs and high cost of necessary facilities for pumping and injection. The major disadvantage of groundwater recharge using effluent water is the increased risk of groundwater contamination. (Hammer 2001, 514; Tchobanoglous et al 2003, 1422.)

5.2 Effluent Disposal

When wastewater has undergone treatment, the effluent is either reused or disposed to land or water bodies. But generally in most cases, effluent water is discharged into water bodies which give a reason for the sighting of treatment facilities close to lakes or rivers. Having said this, it must always be put into account the implication of the discharge i.e. the way and manner by which the discharge would affect the water bodies and aquatic life.

The effluent water must have a very minimal amount of organic materials so as to avoid the disintegration of dissolved oxygen in the water body. Also the discharge is carried out depending on the nature and characteristics of the receiving water body which makes it paramount that many factors are considered before a decision is made to discharge effluent into a particular water body. Difference in PH levels for instance is one factor because adverse difference in PH could be detrimental to some aquatic animal life. Also, other factors such as depth stratification due to temperature and salinity, current reversal, wind circulation, velocity of the water flow are also taken into consideration. When it comes to the effluent, the salinity and temperature of the effluent water is taken into consideration. It is important that the effluent is discharged into water bodies which are a bit distant from locations where it would be accessed for direct human consumption. When effluent is discharged into water bodies, there have to be proper vertical mixing so as to avoid unnecessary foaming. In such a case, to ensure even distribution of the effluent across rivers, a tool called a multiport diffuser is used to aid the mixing and distribution and this tool extends across the width of the river. A diffuser works in such a way that it discharges the effluent through series of holes along a pipe which extends through the river. (Tchobanoglous et al 2003, 1435.)

6 THE CENTRAL WASTEWATER TREATMENT PLANT IN POZNAN

6.1 Historical background

The central waste water treatment plant is located north-east of Poznan, in the township of kozieglowny. The facility is located on the right bank of the Warta River and occupies an area of approximately 60 hectares. The idea to construct a wastewater treatment plant on the right bank of the river was first put forward in 1954. However, technical and economic assumptions for the erection of a central waste water treatment plant and a technical design were set out only in the municipal investment plans in 1971 – 1972.

The documentation provided for three construction stages include:

1st stage- mechanical treatment plant for Q = 55,000m^3/day

2nd stage- mechanical treatment plant with preliminary biological treatment for Q = 260, 000 m^3/day

3rd stage- biological treatment plant for Q = 330,000 m^3/day

Work on the mechanical section of the treatment plant with comprehensive sludge management commenced in 1974.

Waste water started to flow on 31st December 1985 while the then substitute investor – the Development Authority for the city of Poznan- handed over waste water line 1 for use on 1st January 1987, with sludge line 1 following on 1st of January 1989. On 5th November 1991, the minister of environmental protection, natural resources and forestry enacted a regulation which made it mandatory to dispose biogenic compounds. A technology design for the central waste water treatment plant was elaborated- this taking into consideration the requirements set forward in the new regulations with technical and economic assumptions following thereafter. (Aquanet Journal 2009.)

From the year 1995 to 2009, the central waste water treatment plant has undergone several modifications to meet present say demands. Most of the refurbishments centred on the modernisation of existing facilities including the enlargement to a capacity of 200 000m3/day. Also there was construction of a new and highly efficient biological section which incorporates a system enabling the integrated biological removal of carbon, nitrogen and phosphorus. The refurbishments were very capital intensive and cost about 340 million PLN (Polish Zloty) with the city of Poznan covering 50% of costs and investment outlay. (Aquanet Journal 2009.)

6.2 Capacity of the wastewater treatment plant

The capacity of the central wastewater treatment plant confirms that the plant is one of the largest of such facilities in Poland. The listing below shows the values of capacity parameters.

The designed average capacity Q = 200,000 m^3/day

The designed maximum capacity = 260,000m^3/day

Actual average working capacity Q= 124,465m^3/day

The hydraulic capacity of the central waste water treatment plant allows it to accept steadily larger quantities of wastes and is supported by the gradual development of the wastewater network in the city of Poznan and neighbouring municipalities, which is progressing in accordance with the investment plans. At present, the plant could accept an additional 70,000 m^3 of wastewater without any problems arising. (Aquanet Journal 2009.)

6.3 Process line of the central waste water treatment plant (CWTP)

The central waste water treatment plant was one of the first of such large facilities to be built in Poland which had a biological wastewater treatment system and with the additional removal of biogenic compounds, was designed, constructed and put into operation. The technological efficiency of the plant is of very high standard while the quality of treated wastewater makes it one of the leading wastewater treatment facilities in both Poland and Europe. (Aquanet journal 2009.)

The screening is transported to press washers where they are washed and dewatered and subsequently collected in solid waste containers. The sand trapped in de-sanders is placed in sand craters using blade scrapers, from where it is forced through to sand separators with the aid of sand pumps. The sand separated in separators is gathered into containers, while the effluent is returned to the de-sanders. The washed and dewatered screenings and sand are transported away for storage at municipal waste dumps. (Aquanet journal 2009.)

In the biological line, an integrated biological system is applied for the removal of carbon, nitrogen and phosphorus compounds in a process of low load active sludge system. The biological line is equipped with six bioreactors with a capacity of 25,000m^3 each. Each bioreactor comprises of six tanks as follows:

-An anoxic tank for the process of de-nitrification of re-circulated sludge.

-An anaerobic tank for the phosphorus removal

-An anoxic tank for the de-nitrification of waste water

-An intermediate tank (which could function as either an anoxic or aerobic tank)

-An aerobic tank for the nitrification and oxidation of wastewater

-A de-oxidation tank (used to deoxidise the internal recirculation stream)

The anaerobic and anoxic tanks are fitted with mixers which serve to maintain the biomass suspended throughout the tanks. The anaerobic tanks in turn are fitted with membrane diffusers for fine and clear aeration. Air is channelled from the blower station at a maximum rate or quantity of 120,000m^3/hour. The quantity of air could be controlled by referencing either to a given concentration of oxygen or to a concentration of ammonia nitrogen measured on a constant basis. The quality of the nitrates in the outflow is regulated through internal recirculation by means of pumping mixers. (Aquanet journal 2009.)

Following biological treatment, the wastewater is channelled to final clarifiers where biological sludge is separated by settling. Having passed this complex cycle of treatment, effluent is still subject to routine tests which confirm whether or not the product satisfies requirement standards. The remains of biological sludge returns to the bioreactor as circulated sludge otherwise known as activated sludge and then the excess sludge is removed from the wastewater treatment system and transferred to a sludge management facility.

GRAPH 4. View of one of the bioreactor sedimentation tanks

GRAPH 5. Bio-reactor tanks are built with brick concrete walls

6.3 Sludge management

During the waste water treatment process, preliminary sludge is produced in primary sedimentation tanks and biological sludge in secondary sedimentation tanks. The primary sludge is gravitationally thickened whereas excess sludge is mechanically compacted in sludge compactors. The process of compaction of the excess sludge is chemically supported with the use of flocculants prepared at the processing station. The station allows the use of agents in the form of powder and emulsions. Mixed sludge is fed to the separate digestion tanks where at the temperature of 35^0C, the organic compounds are broken down in the process of anaerobic digestion, which lasts for about 30 days. (Aquanet Journal 2009.)

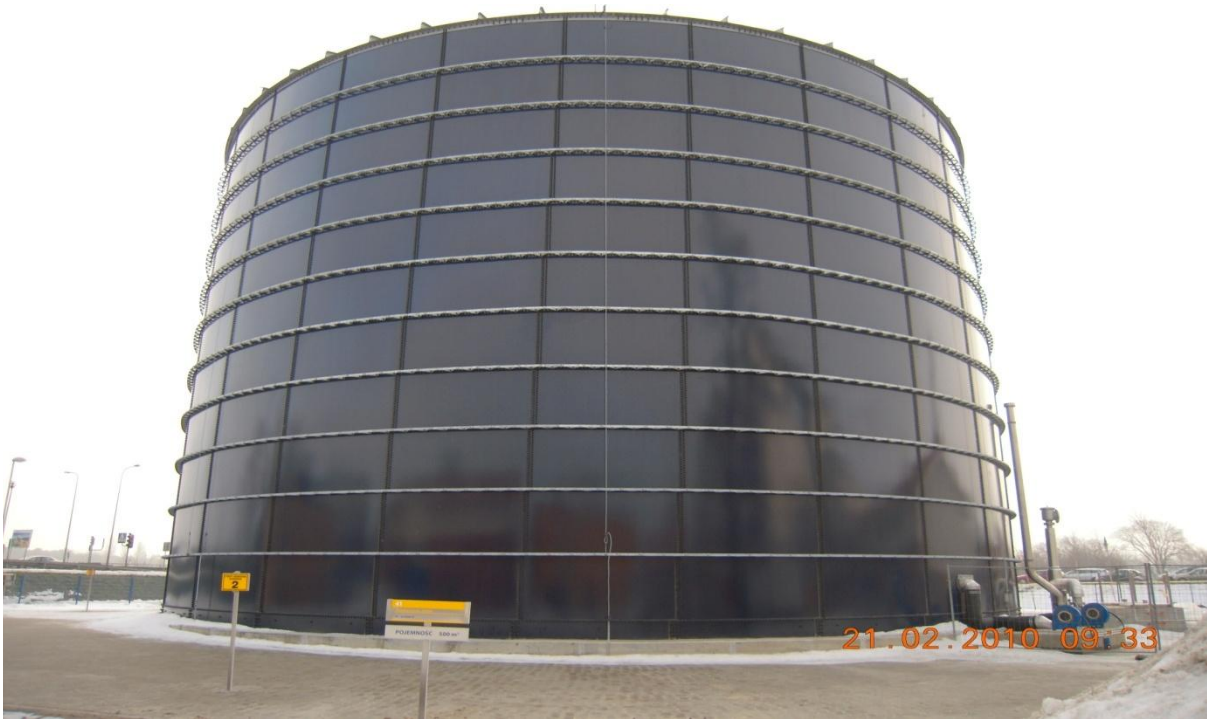
Following degassing and equalization in equalization tanks, the digested sludge is dewatered on a belt press up to dry mass concentration of about 20%. Similar to mechanical compaction, the dewatering processes is chemically supported with the use of flocculants. Flocculent solutions are prepared at the processing station adjusted for the use of agents in the form of both powder and emulsion. Dewatered sludge is transported to the thermal drying station consisting of three separate drying lines with a water evaporation efficiency of 3050kg/hour each. (Aquanet journal 2009.)

The process consists of mixing in the right proportion of wet sludge with the re-circulated or previously dried sludge. The prepared mixture is then fed from the top to a cylindrical vertical drier with a diameter of 9m and equipped with four shelves which has been heated up to a temperature of about 260^0C. Using specifically designed rakes, the sludge is raked into the hot shelves downwards into the drier in order to facilitate complete evaporation of water. During raking, granulate of diameter greater than 2mm is produced which at the outlet from the drier is cooled down to 40^0C and excess dust is then removed. The finished product is then stored in three silos with a volume of $110m^3$ each. (Aquanet journal 2009.)

6.4 Biogas production and management

During the digestion process, the biomass or sludge is subjected to anaerobic bacteria in a closed vessel called a digester. The volume of biogas i.e. methane produced in this plant in total amounts to about $18{,}000m^3$ in a day. Normally, bio-digesters after anaerobic digestion has taken place produce about 80% of methane and 20% percent Carbon IV Oxide. This percentage might vary slightly depending on the nature of the sludge present. The process takes place in such a way that the biogas is first desulpfurised in the biological bed. De-sulfurisation is necessary so as to extract the hydrogen sulphide gas compound which is present in the sample and if not removed could cause the digester to operate with less efficiency. Elevated hydrogen sulphide concentrations could cause significant problems for the gas engines. Combustion could lead to the formation of Sulphur IV oxide which would aid quick corrosion. Desulfurisation is carried out with both chemical and biological methods.

After desulfurising, the methane gas is collected in two gas tanks after which it is compressed and combusted in three gas generators which produce electricity. Each generating facility has a capacity is 941KWh. Heat recovered at the gas heating facility is utilised for local heating purposes in the treatment plant. There is a heat generating device which heats up the biogas to a required temperature and then sends it via heat exchangers to designated places in the plant for various heating purposes. (Aquanet journal 2009; Renewable energy concepts 2010.)



GRAPH 6. A biogas storage tank designed for storing excess biogas (methane) at the treatment facility.

GRAPH 7. A generating facility used for heating up biogas to higher temperatures thereby producing heat which is utilised for process heating purposes in the plant.

GRAPH 8. A digester which digests sludge anaerobically with the aid of anaerobic bacteria to produce biogas (methane). There are two of such digesters erected in the plant for the digestion process.

6.6 Bioreactor operating parameters

TABLE 4. The working parameters of the bioreactors (Aquanet Journal 2009.)

Parameters	Unit	Value
Bioreactor capacity	m^3	25,730
Average daily working capacity	m^3/day	21,000
Concentration of active sludge	Kg/m3	2.5-4.5
Oxygen concentration (density)	Mg/l	0.5-2.5
Internal Recirculation	%	300-600
External Recirculation	%	40-100
Age of sludge	Day	15-22

6.7 Wastewater testing laboratory

Monitoring of the operation by the central wastewater treatment plant is performed by the wastewater testing laboratory which is located in the plant premises. The wastewater laboratory is duly accredited. The tests performed in accordance with the adopted testing programme allow staff to ensure permanent control over the parameters of wastewater, sludge and effluent at different individual points of the technological process. The water testing facility also does tests for other wastewater treatment facilities in Poland.

As a result of mechanical-biological treatment, the ecological effect of this activity is positive and brings about high waste reduction to a degree ensuring fulfilment of both national demands and the European Union.

The year 2006 was a very successful year for the wastewater treatment laboratory and as a result the testing centre received an accreditation certificate issued by the Polish accreditation centre.

The tests carried out mainly make use of the flame atomic absorption spectroscopy (FAAS) and the inductively coupled plasma mass spectroscopy (ICPMS). In this particular case, the flame atomic absorption spectroscopy apparatus was preferred due to its higher sensitivity and specification as compared to the inductively coupled plasma mass spectroscopy apparatus (ICPMS). The flame atomic absorption spectroscopy (FAAS) is mainly used when you need a more qualitative analysis of samples especially waste water samples while the ICPMS is more like for general purposes i.e. both waste water and pure drinking water analysis. The atomic absorption spectroscopy uses the absorption of light as a measure of the concentration as a measure of the concentration of gas phase atoms. The samples which are in liquid form are sent through an automated system to the chamber which houses a graphite tube which is electro-thermally heated. The water sample after heating vaporises and is atomised. There is a source of light on the left hand side of the machine. The atoms absorb the ultraviolet or visible light and make transitions to higher electronic energy levels. The specimen concentration is determined with respect to the measure of absorption of light. (Aquanet Journal 2009.)

GRAPH 9. A cross section of the Flame Atomic Absorption Spectroscopy (FAAS) machine at the Aquanet laboratory on site.

GRAPH 10. The display unit for the flame atomic absorption spectrometry apparatus

GRAPH 11. An automated sample tray for the flame atomic absorption spectroscopy apparatus.

GRAPH 12. The light emission and absorption chamber of the flame AAS apparatus

Graph 13. An ICPMS machine at the Aquanet laboratory

6.8 Results of tests carried out on raw and treated wastewater

TABLE 5. The results of tests carried out on samples for the month of February 2010 with an overall supply of wastewater (influent) of approximately 126,000m^3/day.

Parameters	Raw Wastewater (Influent)	Treated wastewater (Effluent)	% Reduction of contaminants
	Mg/dm^3		
COD	1158	36	96.89
BOD	483.6	1.7	99.65
Total suspensions	554.8	5.0	99.10
Ammonia Nitrogen	47.64	0.31	99.35
Organic Nitrogen	40.02	2.89	92.78
Nitrogen	86.12	3.20	96.28
Total Nitrogen	87.83	9.24	89.48
Total Phosphorus	15.21	0.62	95.92
Zinc	0.72	0.07	90.28
Total Chromium	0.04	0.00	100.00
Cadmium	0.000	0.000	100.00
Copper	0.27	0.00	100.00
Nickel	0.07	0.00	100.00
Lead	0.18	0.00	100.00
Iron	4.85	0.16	96.70

6.9 New directions and concerns in waste water treatment

In the world today, there is a current trend whereby effluent reuse policies tend to be considered as compared to earlier times due to diminishing water supplies. This could be said to be responsible for a system known as twin water systems. Twin water system supply could be defined as a system whereby there is supply of both potable and non potable water flowing from two separate and different water distribution networks. Also, satellite reclamation system which could be defined as a system whereby the wastewater influent is systematically withdrawn from a collection system and treated and later on reused on a local scale thereby minimising transportation, treatment and logistic costs. (Tchobanoglous et al 2003, 1634.)

We must not fail to recognise the potential threat posed by the possible existence of microbes and chemical water contaminants which could emanate from the presence of new trace elements. This is the main reason why the use of effluent as a potable source of water would remain debated and almost impracticable.

In recent times, there have been new technological advancements to tackle this impending problem and to ensure higher removal rates of water contaminants. These technologies include, advanced oxidation, ion exchange, air stripping, carbon adsorption as well as pressure driven membranes. Membrane technologies which were previously restricted to removal of salt from water are now being refined and tested for the production of better quality water for potable indirect usage. A lot of research is ongoing and it is expected that there would be more efficient processes and effluent production in the near future.

In the area of sludge management, there have been significant amount of interest in the production of sludge with better quality, less weight, and safely reusable. When compared to advancements in wastewater treatment, there have been fewer inventions in sludge management technology. Despite that fact, there have been some new technologies which include the use of powerful heat dryers, oval shaped bio-digesters and high-solids centrifuges.

Also there have been new modifications to digesters types which include the auto-thermal aerobic digestion process and temperature-phased anaerobic digesters. These are improved digesters which are less cost intensive and more efficient in producing the methane gas which is needed for electricity generation and heating purposes. These digesters also make it possible for the production of bio-solids that would contain very trace and undetectable amount of pathogens. (Tchobanoglous et al 2003, 1635.)

CONCLUSION

The need for effective and efficient wastewater collection, treatment and effluent management so as to have a healthy environment and populace cannot be over emphasised. Due to this, there have been extensive and diversified researches into this topic which have led to significant improvement in treatment techniques, sludge and effluent management over the years.

This thesis focused on the assessment of wastewater treatment with special reference to the Poznan wastewater treatment plant in western Poland and it dissects how the process of purification takes place and is carried out. This research work focuses on the key issues responsible for the different strategies undertaken during purification. In the end, based on the level of reduction and in some cases complete eradication of contaminant organic and inorganic materials from the raw wastewater, we could conveniently say that the treatment methods and applications adopted in this treatment facility is of high efficiency and standard. The city of Poznan has a total of just over half a million inhabitants and there is a reasonable amount of effluent supply to the treatment facility. The treatment process of the plant is of very high standard and it is one of the most efficient treatment units in the European Union.

The cost of running a wastewater treatment plant could be massive due to the enormous amount of processes involved and energy consumed. The ability to maximise energy savings plays a major role in the reduction of overall wastewater treatment costs. Engineers should be able to identify available energy saving approaches during the design phase of the treatment facility and collaborate with plant staff to evaluate, select and implement the most appropriate options available.

The need for humans to become more water efficient i.e. to get more from a given amount for water so as to prevent unnecessary waste and contamination of water gave rise to the recycling i.e. treatment and reuse of treated water. So we can confidently say that wastewater treatment should be encouraged and new ideas for more efficient treatment methods with less treatment costs should be welcomed.

Limitations to the treatment process could be said to be the biochemical oxygen demand (BOD) which takes some time i.e. 5 days before a result could be obtained but it is still a universally adopted method of evaluating the biodegradable fraction of organic matter.

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